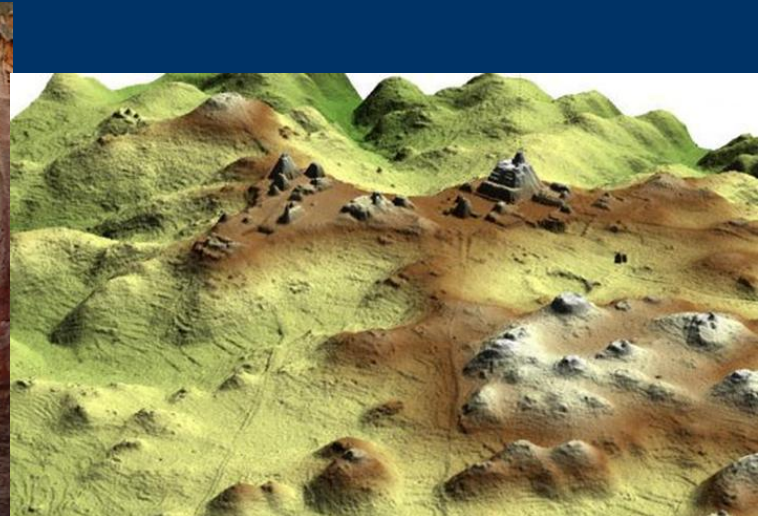
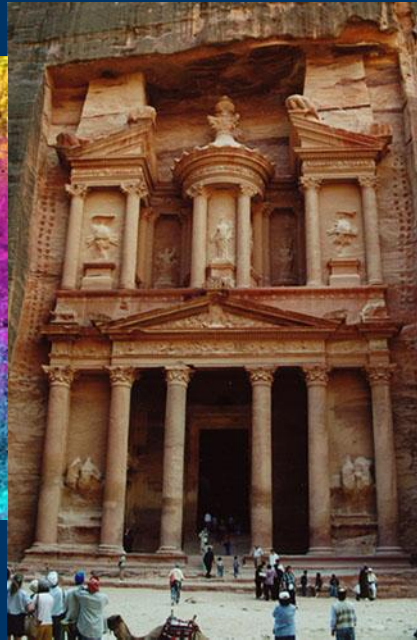
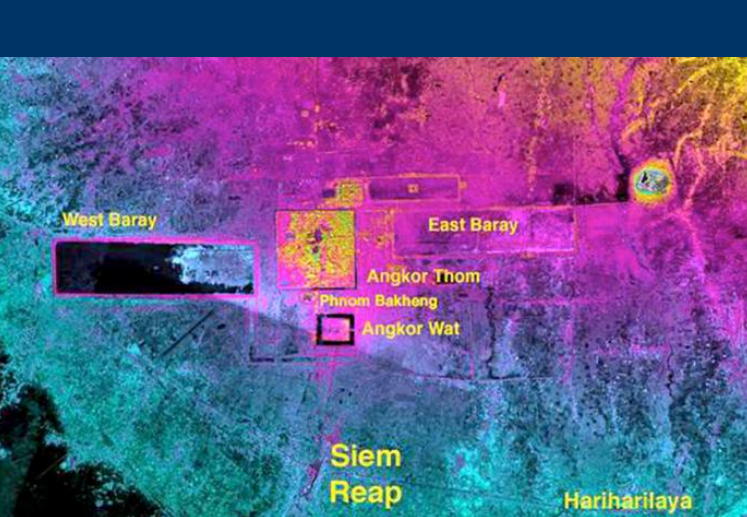


Aerial and Satellite Remote Sensing for the Understanding and Protection of Cultural World Heritage



Huangshan Dialogue on UNESCO Designated Places and Sustainable Development: 27 May 2014

Huangshan City, Anhui, China

Douglas C. Comer, Ph.D., Co-President, ICAHM

Principal, Cultural Site Research and Management, Inc. (CSRM)

dcomer@culturalsite.com

Would Protected Areas Exist in the Absence of

Tourism?

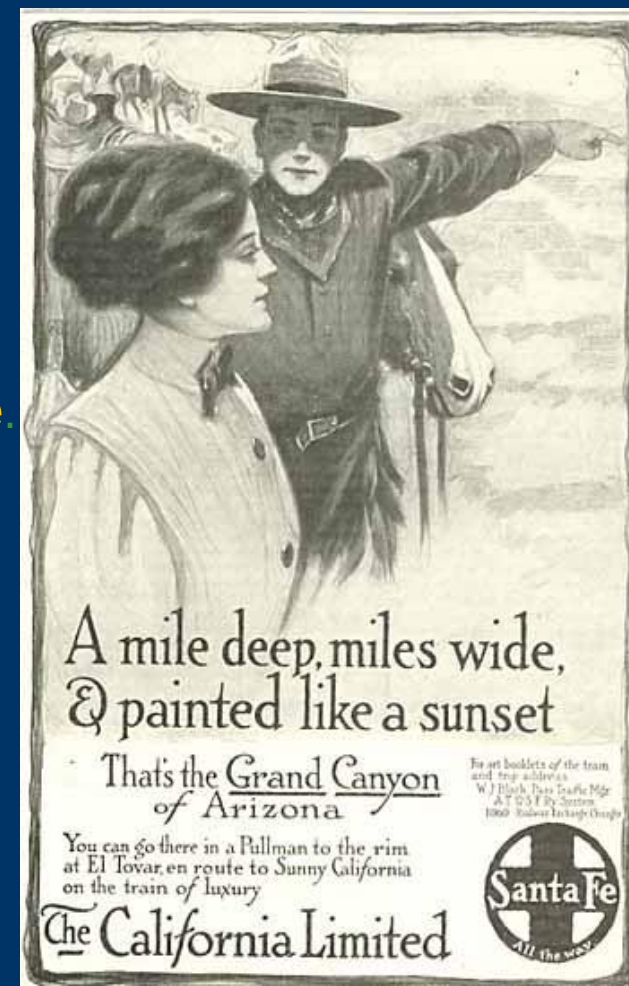
The oldest system of protected areas, the US National Park Service, was established in part to promote tourism

The first national park was established by The US Congress only after energetic lobbying by the Chairman of the Union Pacific Board.

The margin was one vote.

The US National Park Service served as the model for the World Heritage List

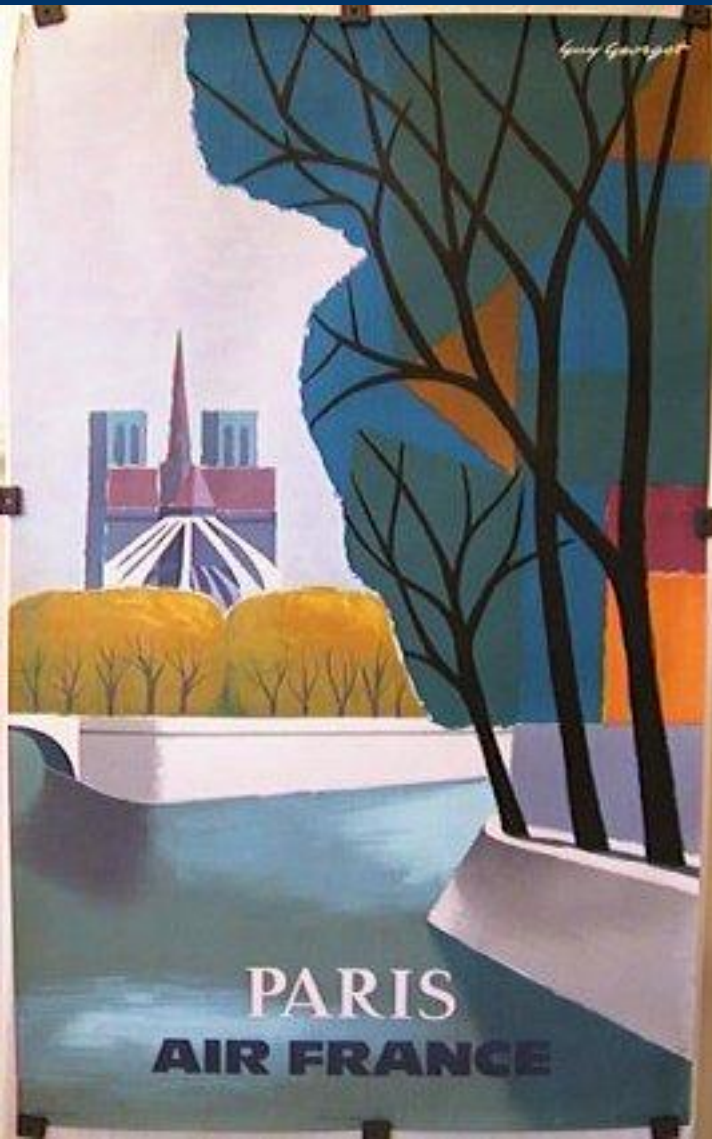
President Richard Nixon sent members of the US National Park Service to Paris to help draft the World Heritage Convention. It was signed 100 years to the day after the National Park Service was formed.



Economic Benefits

Tourism is regularly listed as the largest or second largest industry in the world

- This includes all travel, including business



Example: In Jordan, it is first or second in each year

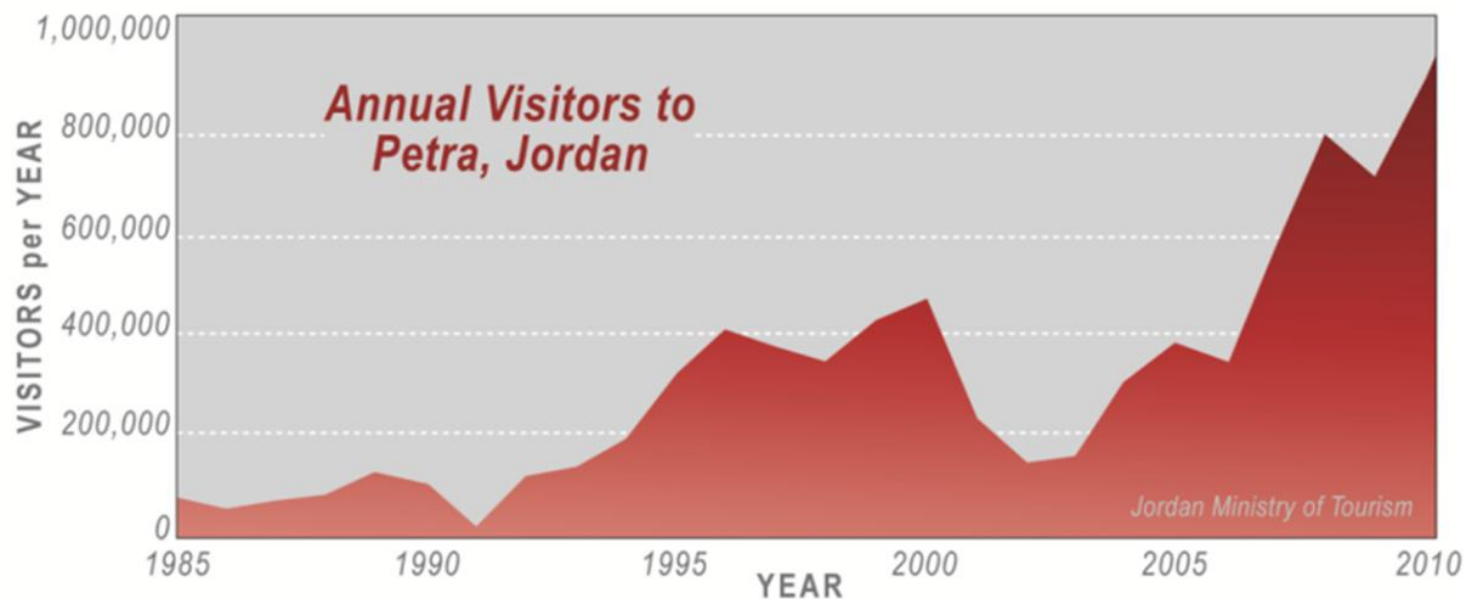


World Heritage Designation Just The First Step

Recognition as a World Heritage Site is only one element in sustainable tourism

At Petra:

- Roads and better accessibility by air
- Development of tourism amenities
- Marketing: advertising, working with receptive operators, museum exhibits



What Have We Learned from Petra?

Damage will occur when the number of visitors exceed the capacity to manage visitors

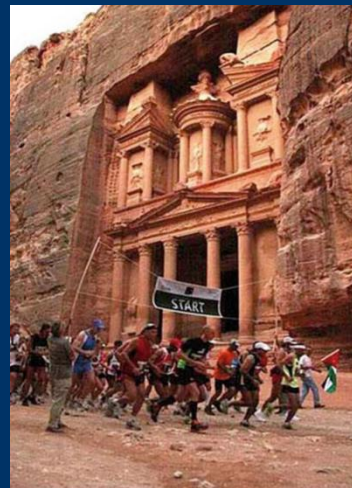
We can monitor damage, but by the time it is detected, it is too late



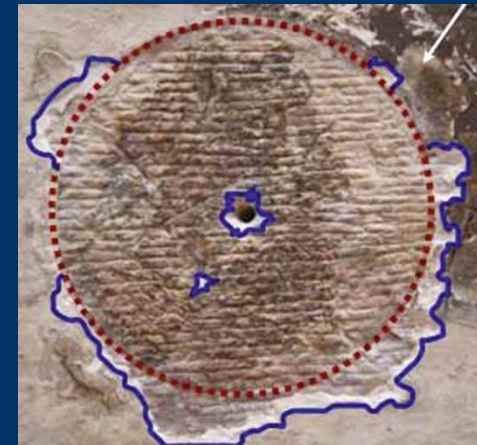
Although it has been well-established that seating tourists in the Theatre at Petra had already resulted in loss by abrasion of many ancient stonemason's marks, it is still permitted during special events

We must understand the processes that produce damage before the damage is done

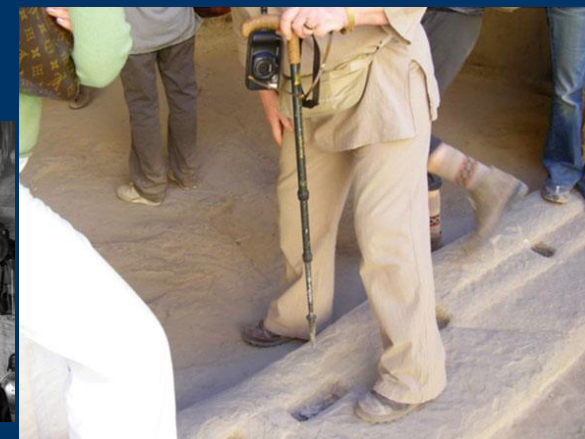
These can be seen at Petra and elsewhere



Set-up and take-down of equipment for events, including seating, props, cameras, lights, sound systems, had produced serious damage to archaeological materials



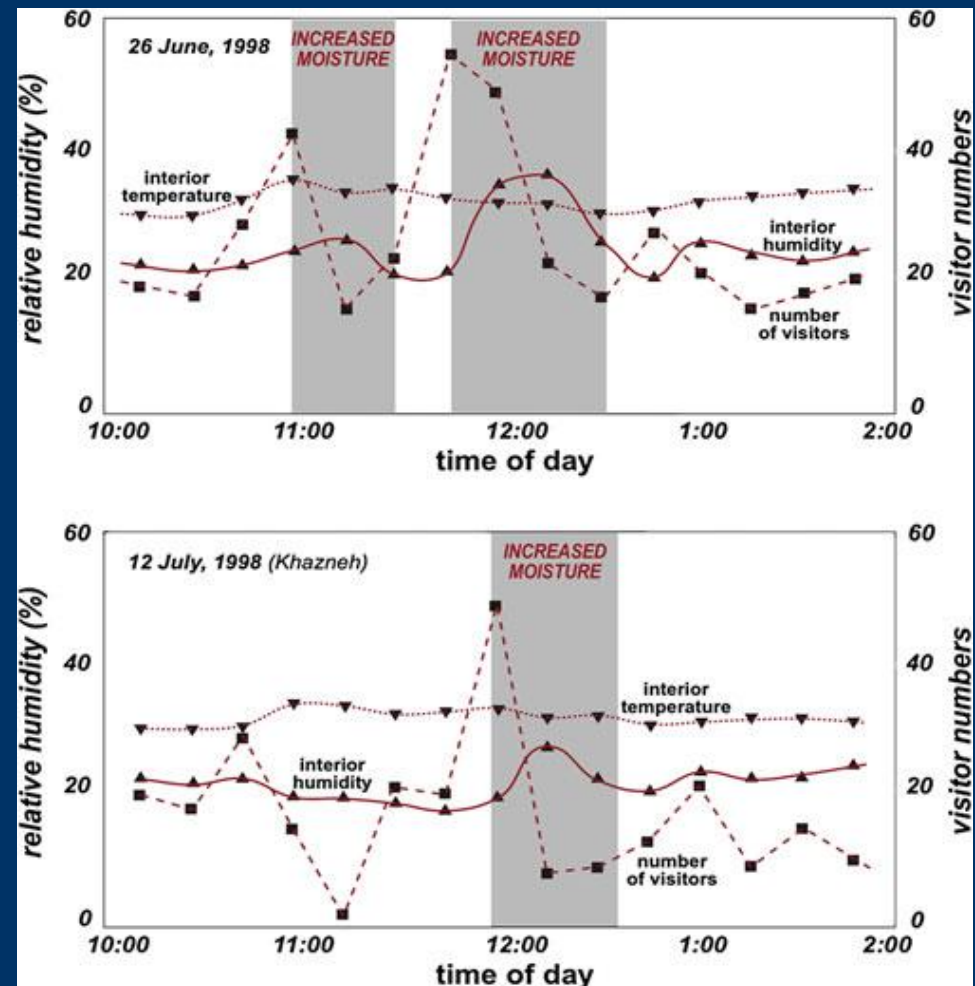
While visitors wear slippers in historic houses, tourists carry pointed walking sticks in archaeological sites



The Presence of Humans Can Alter Small Scale Environmental Conditions

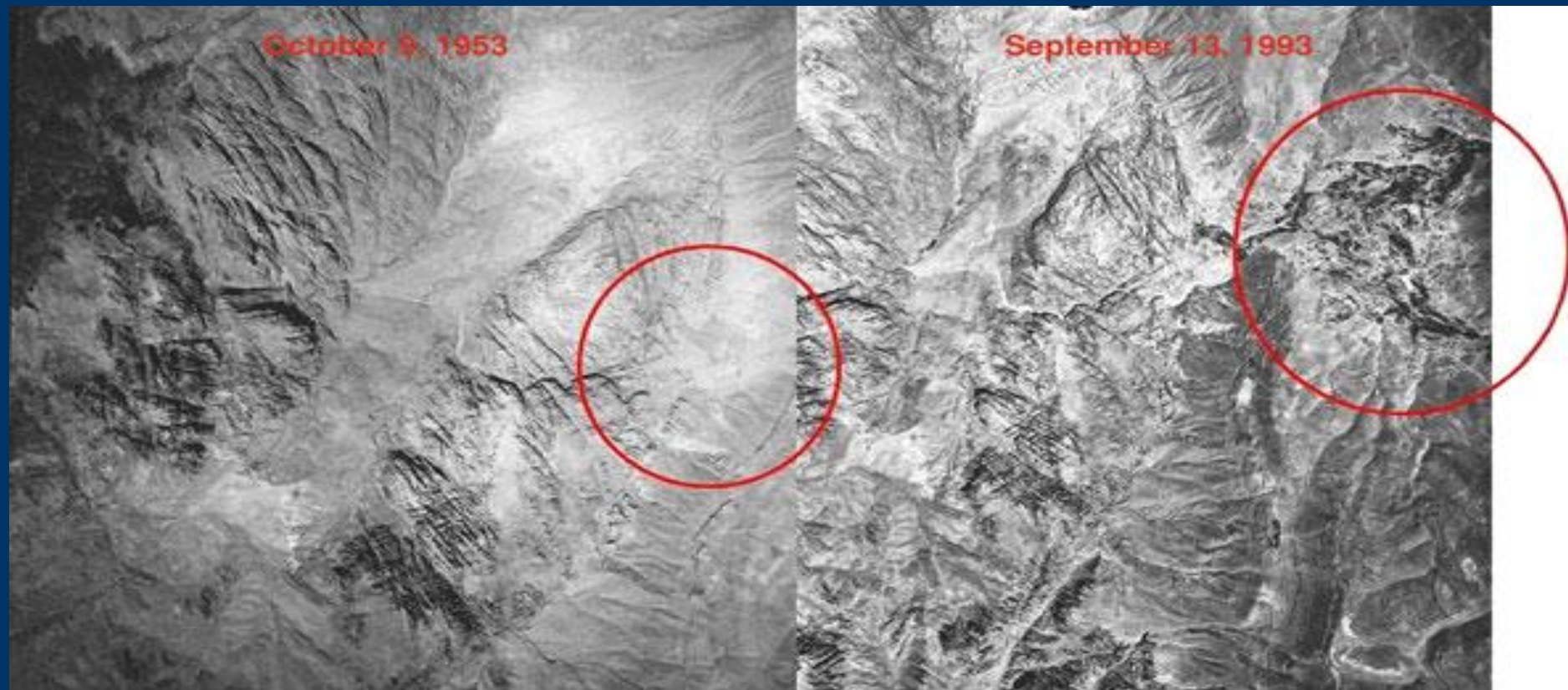
Graphs representing the relationships between visitor numbers in Al-Khazneh and the changes in relative humidity.

The gray areas highlight the large spikes in chamber humidities that occur as a function of in-tomb tourist respiration, perspiration, and transpiration



The Presence of Humans Can Alter Large Scale Environmental Conditions

- **Systemic damage** Development in the vicinity of a protected area produces environmental change. Heavy development can have devastating results.

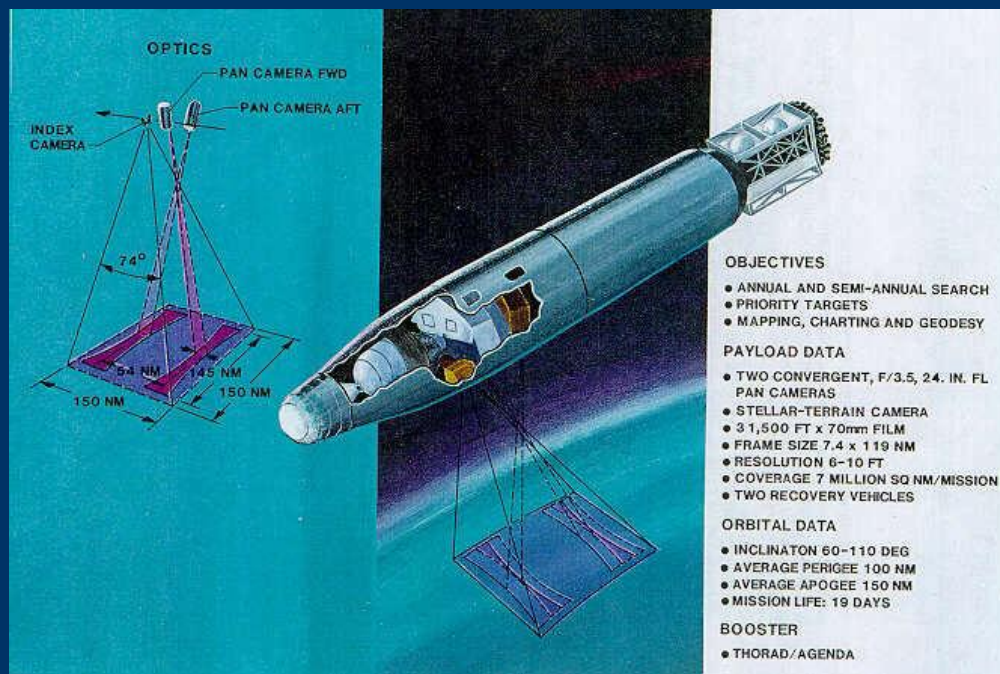


History from Space

NASA becomes operational
October 1, 1958

Corona Program begins
June, 1959

First Landsat launched July
23, 1972



Tell Rifaat in
northwest
Syria

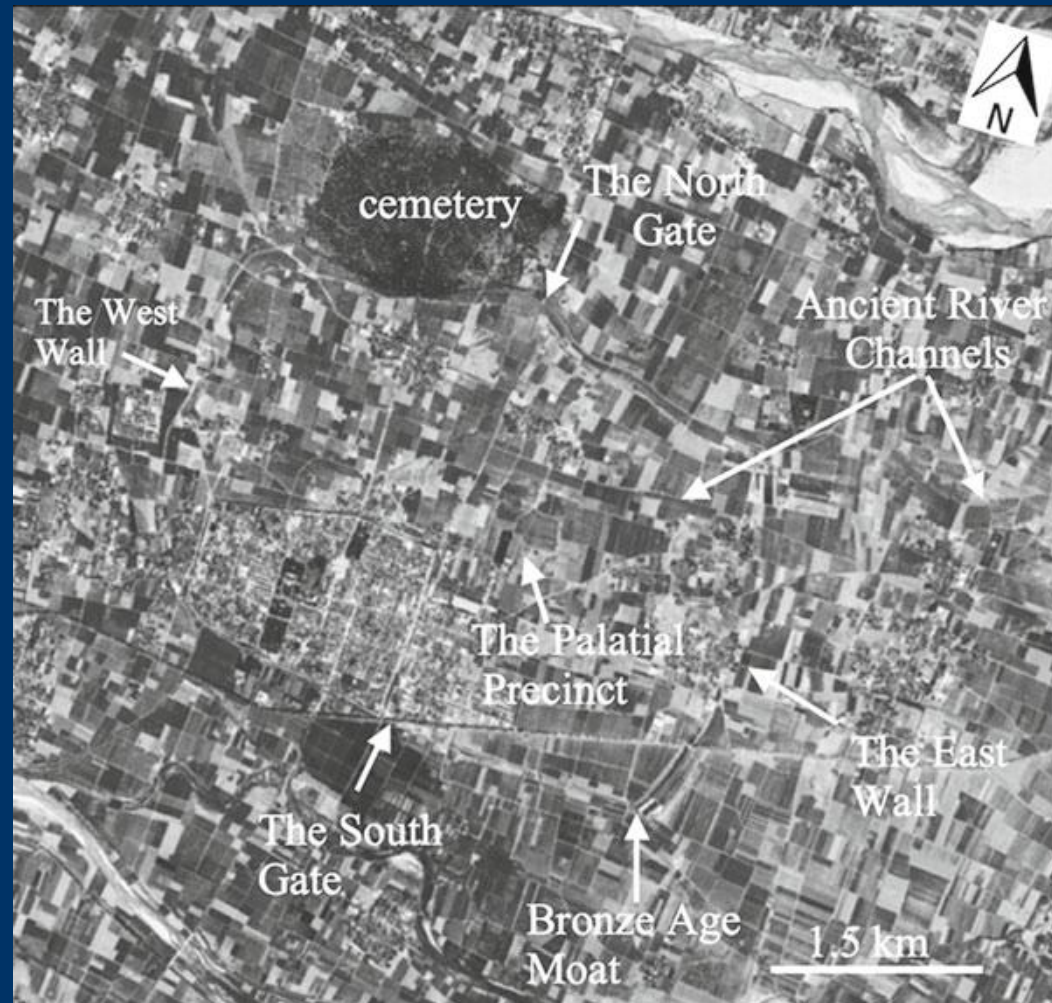


ona.cast.uark.edu/index.html

<http://corona.cast.uark.edu/index.html>

Archaeological Landscapes of China and the Application of Corona Images

It is possible to compare the 1966 Corona image of Qufu with results from the 1977-78, archaeologist Zhang Xuehai and his team from the Shandong Provincial Institute of Archaeology conducted a decade later to identify urban features associated of the Bronze Age city (Fig. 5.2). Some of the prominent features include: the rammed earth wall, the moat surrounding the Bronze Age city, the early imperial palatial foundation in the center of the city, several historical temple complexes (represented by the black strips from concentration of cypress trees in courtyards), and a large historical cemetery north of the city site (National Bureau of Cultural Relics 2007 : 383).





Photogrammetric analysis of stereo pairs to make DEMs

Construction of impervious
surfaces upslope from the
Petra core has changed the
dynamics of water flow at
Petra

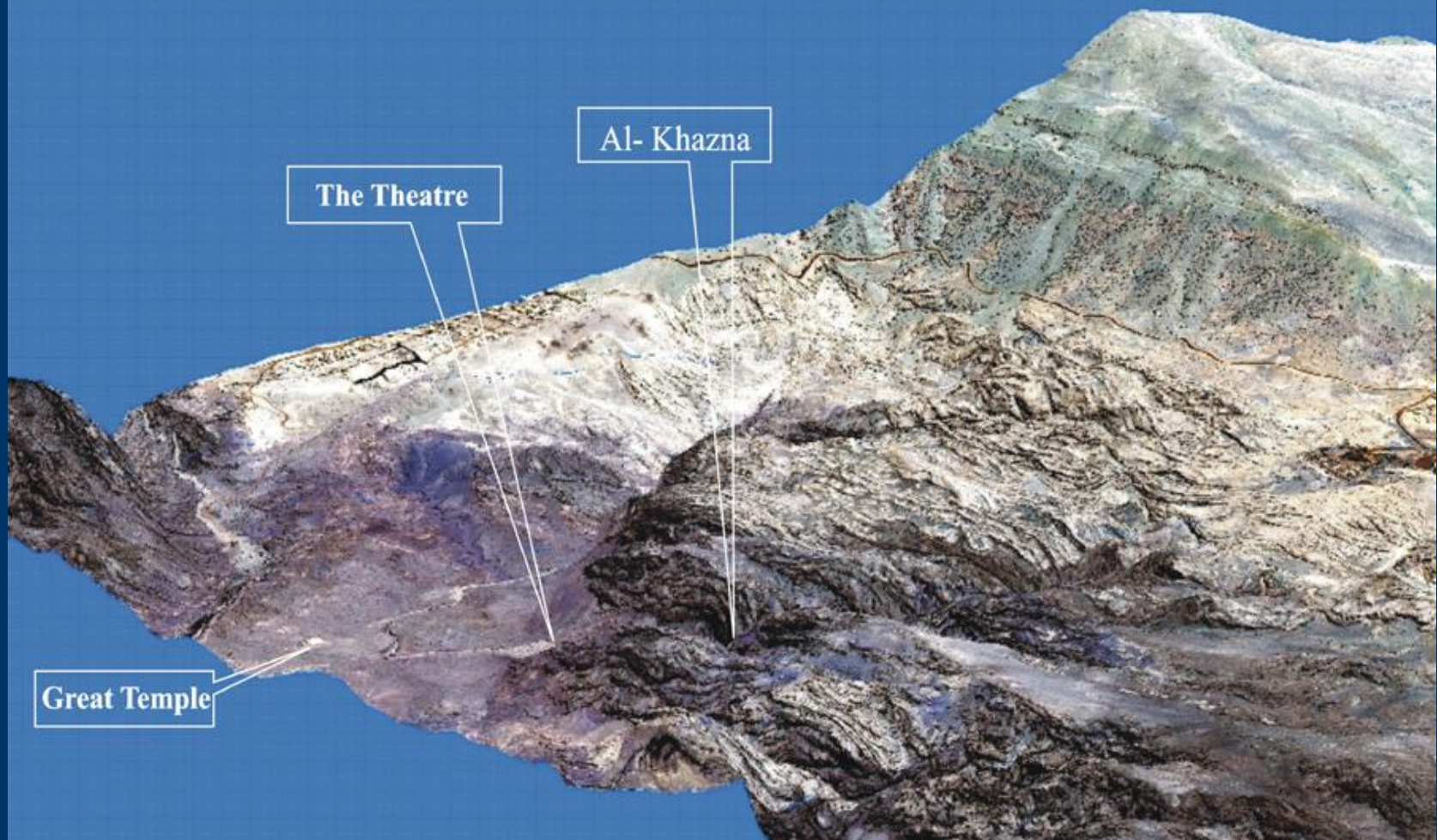


Petra Flow Accumulation Model



Petra DEM from ASTER Images

Petra Center



Fields once buffered water flow

Seen in
IKONOS
Drape

IKONOS
satellite
image
courtesy
DigitalGlobe



Nabataean Fields

1/ Map below

The Nabataeans made their living by taxing international trade caravans. The map shows the caravan routes which covered the ancient Near East at that time. It also demonstrates the waxing and waning of Nabataean influence in the area over a period of some 500 years.

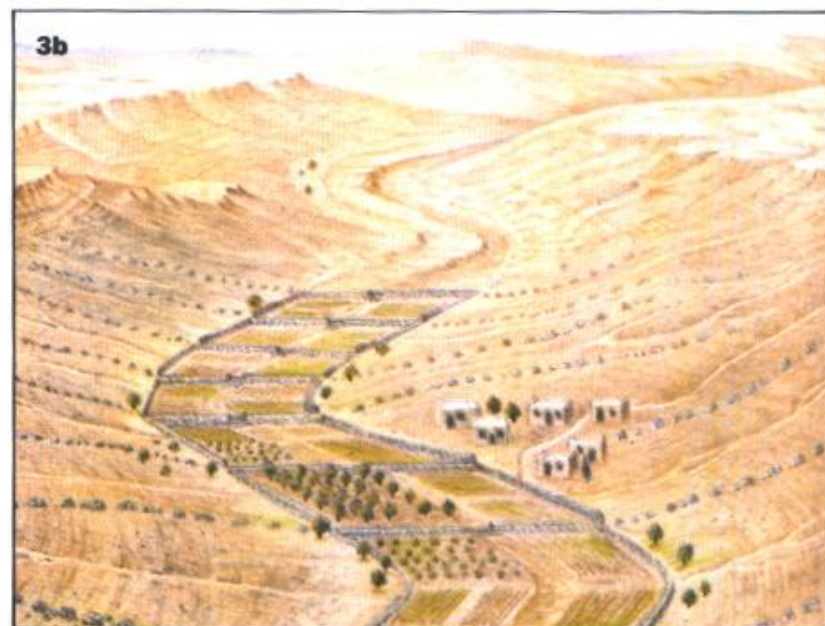
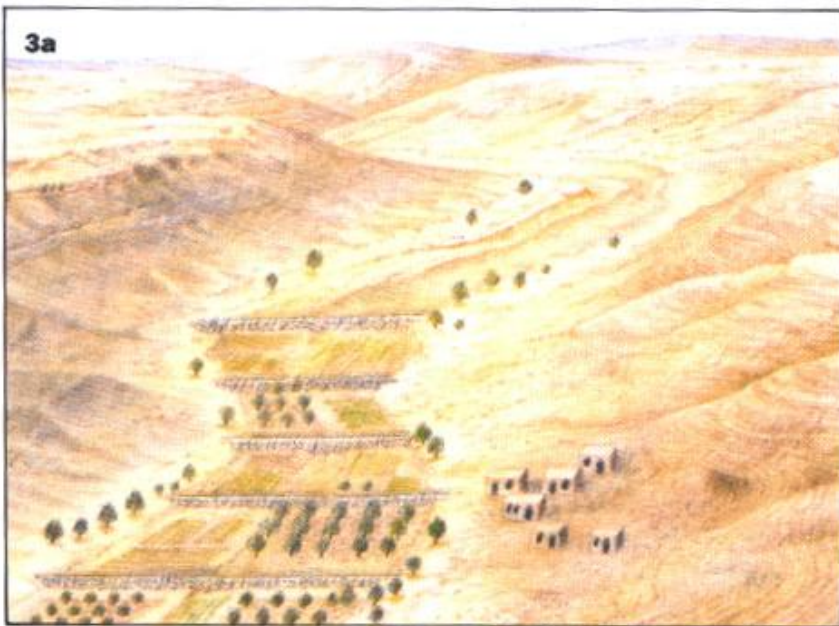
3a and 3b/ Below

These reconstructions show the irrigation methods described above. The terraced wadi (3a) is still used today by the bedouin. Remains of runoff farms (3b) can still be found throughout the Negeb. The example shown is based on one discovered in the vicinity of 'Avedat.

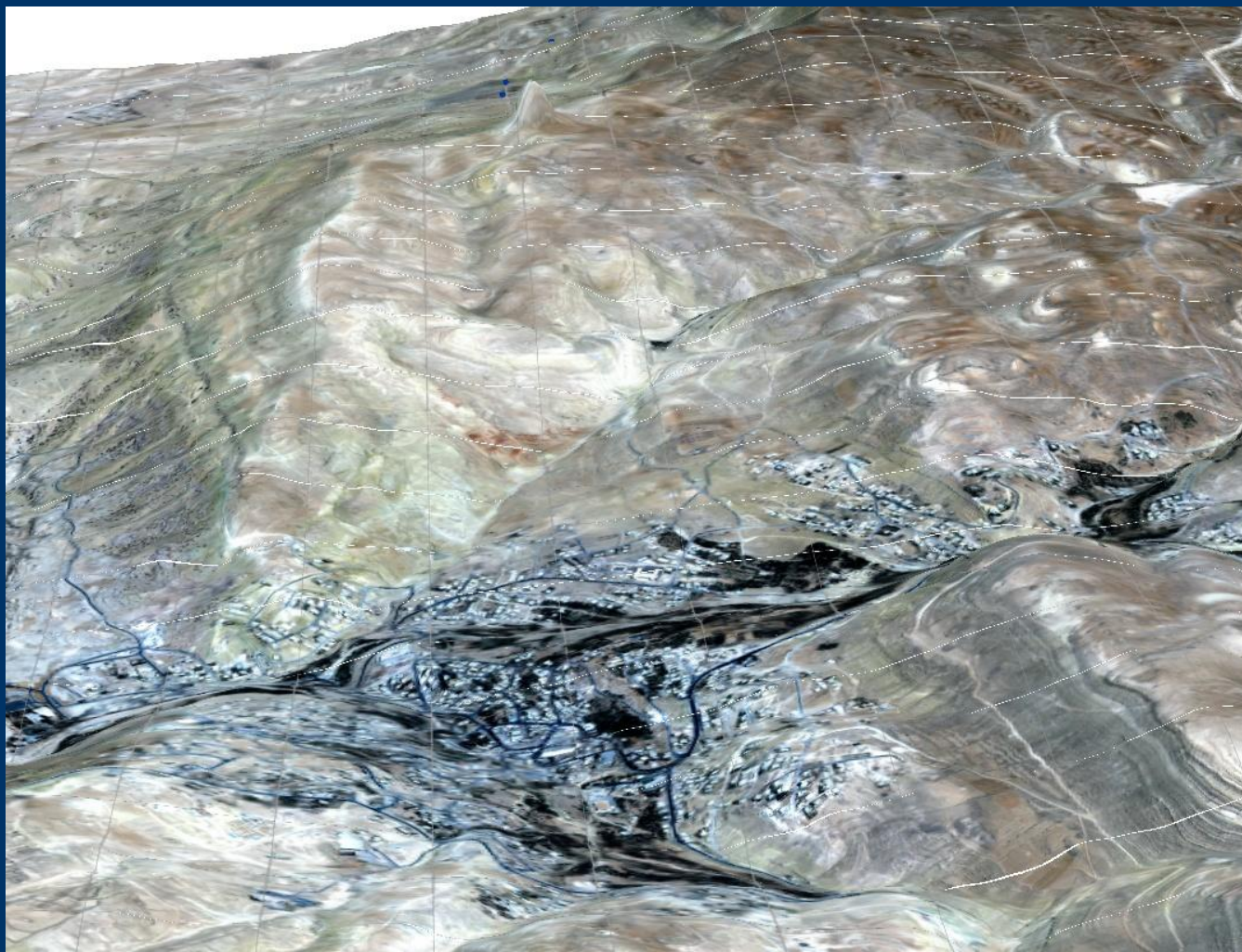
and dates. The crops were unlikely to have changed since the Nabataean period.

...THEY HAVE TURNED ASIDE AND GONE AWAY. THEY DO NOT SAY IN THEIR HEARTS, "LET US FEAR THE LORD OUR GOD, WHO GIVES THE RAIN IN ITS SEASON, THE AUTUMN RAIN AND THE SPRING RAIN, AND KEEPS FOR US THE WEEKS APPOINTED FOR THE HARVEST".

JER 5.23-24



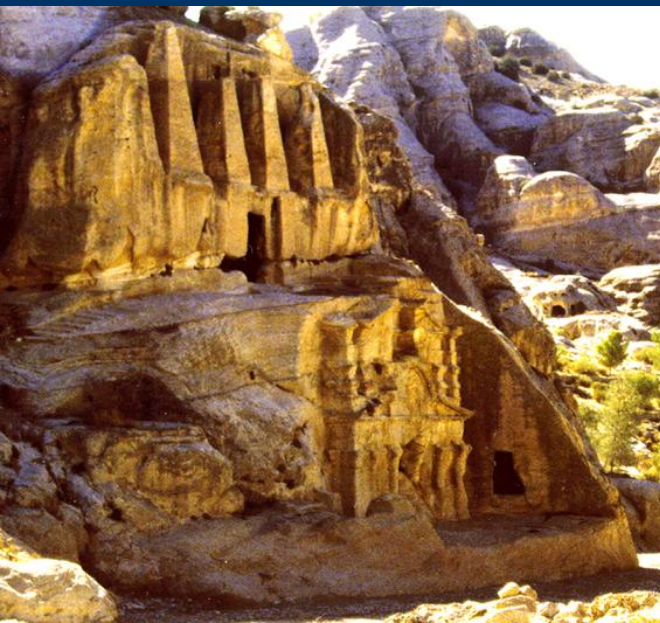
Identifying Problematic Landscape Change



Flood Damage in Wadi Musa November, 1999



Salt Wedging Undermining Case- Hardened Exteriors



Tourism and Preservation

SPRINGER BRIEFS IN ARCHAEOLOGY
ARCHAEOLOGICAL HERITAGE MANAGEMENT

Douglas C. Comer

Tourism and Archaeological Heritage Management at Petra

Driver to Development
or Destruction?

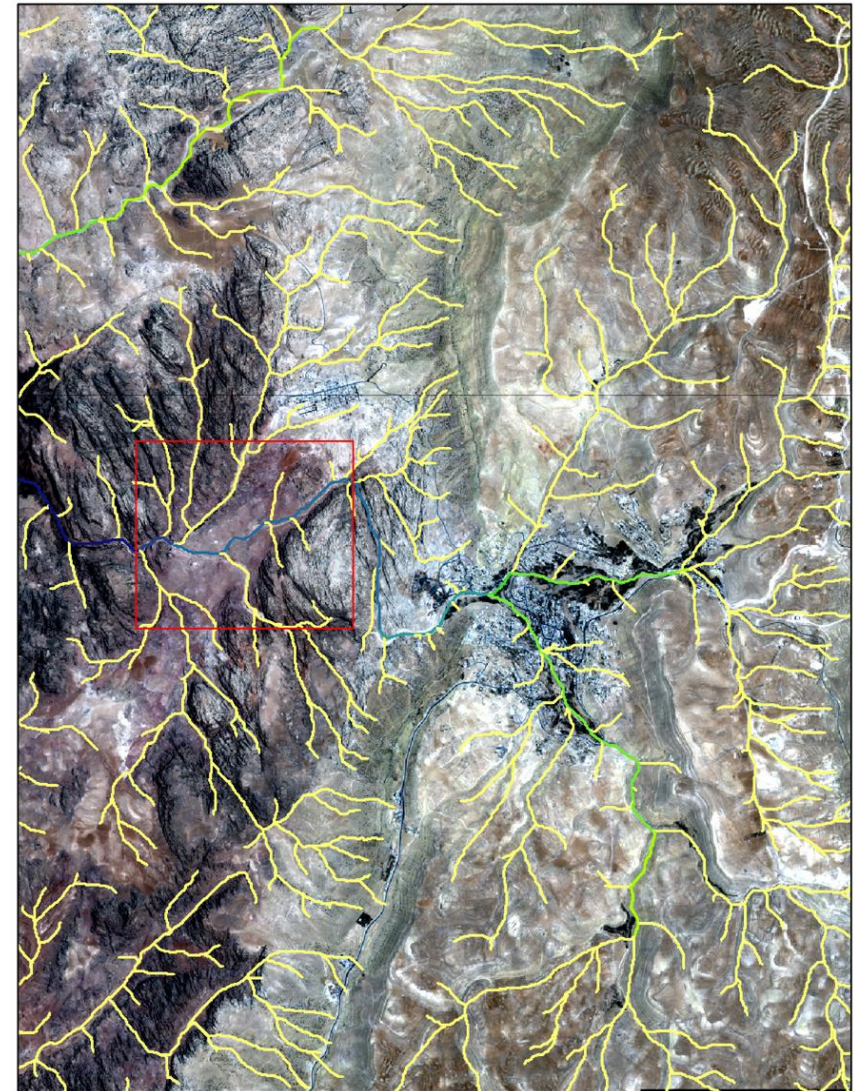
ICAHM launches a series
of publications about
destructive effects of
poorly managed
tourism

- Petra
- Machu Picchu
- Angkor
- Pompeii

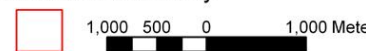
Interpretation from Remote Sensing

**If 16.5% of
precipitation were
captured within
this watershed, it
would support
30,000 people to
the standards
typical to the
urban ancient
world**

Petra Flow Accumulation Model



Core Area of Ancient City

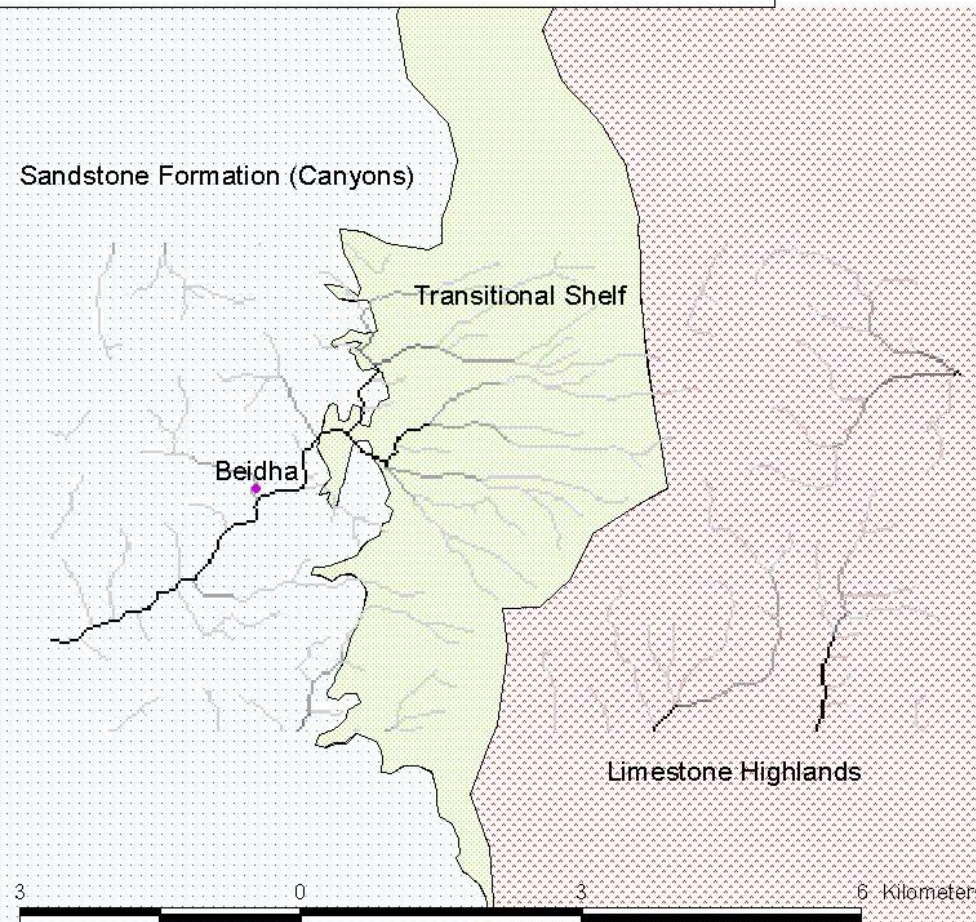
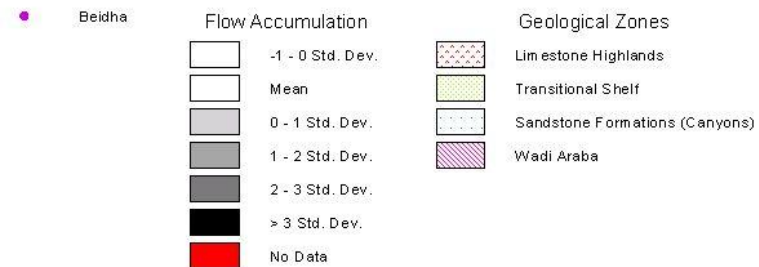


Flow Accumulation



Geological Zones from Synthetic Aperture Radar (SAR) Data, Hydrology from DEM (which can also be produced from SAR)

Beidha Region Topography



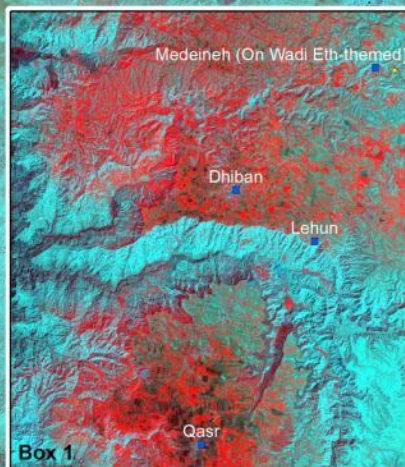
Normalised Difference Vegetation Index
Red (more moisture/ vegetation): 1
Blue (less moisture/ vegetation): 0
Date Acquired: 8th March 2002

- Agricultural Terraces
- Nabataean Temples

WGS 1984
UTM zone 36N
30.0° W 35.2° N



See Box 1



Multispectral and
Hyperspectral

Landsat,
Environment,
Archaeology

Distribution
of Fields
and
Temples

NDVI image:

Red=healthy
vegetation

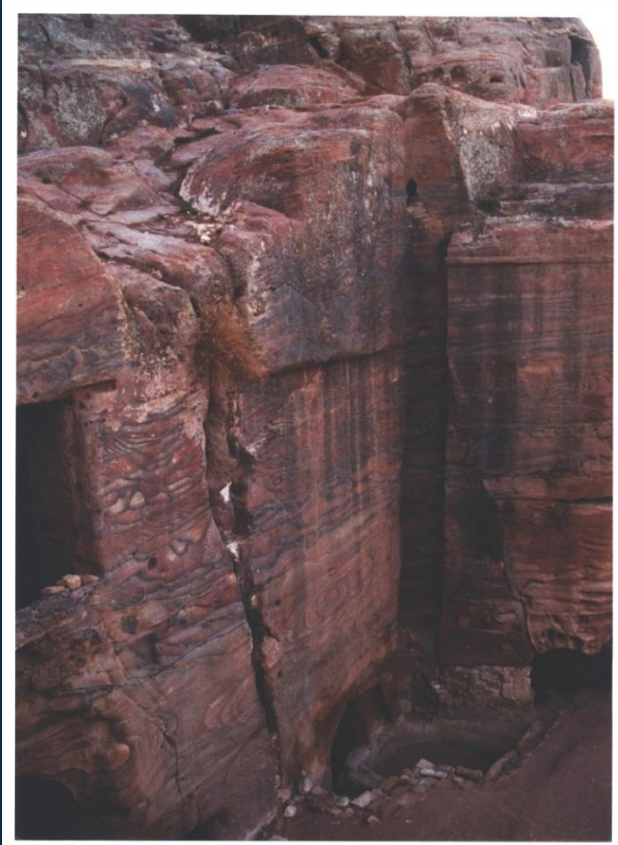
Blue dots are
Nabataean
temple

Yellow dots
are
Nabataean
fields

All fall within
zone
conducive to
healthy
vegetation

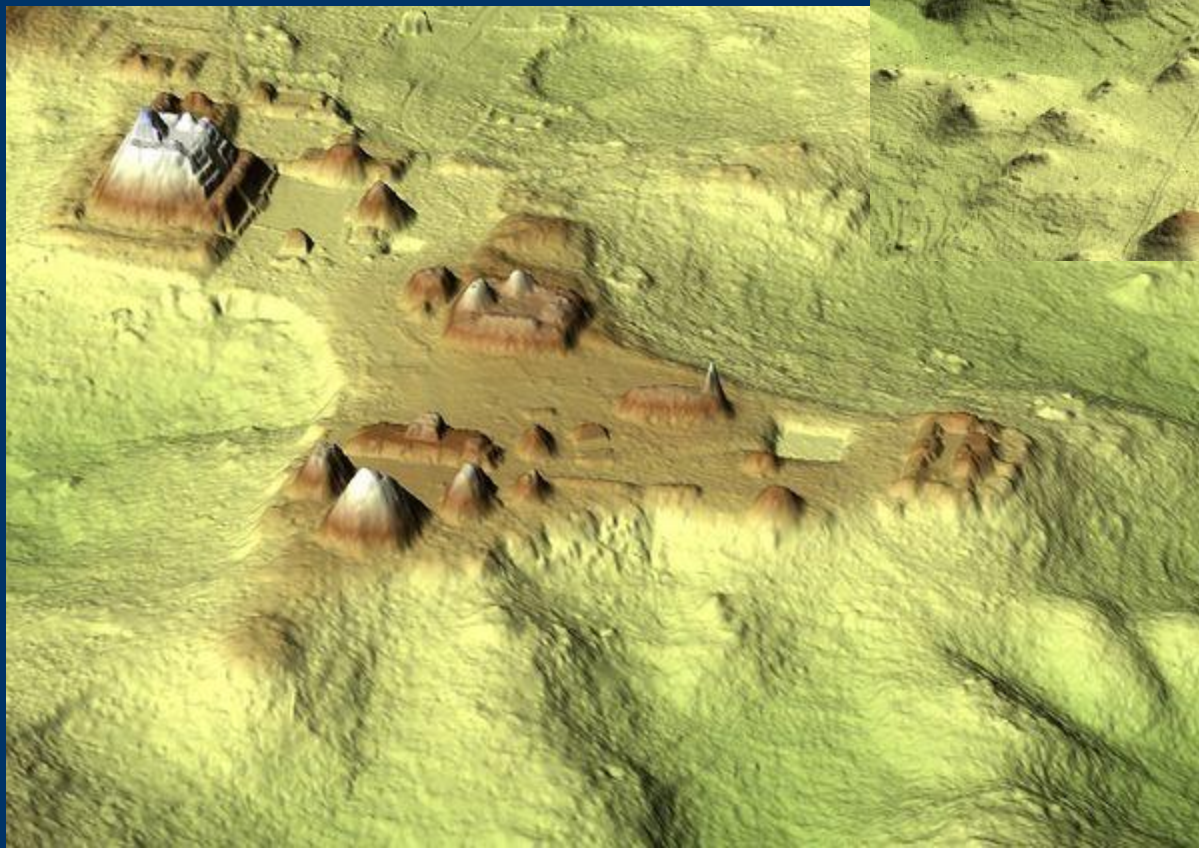
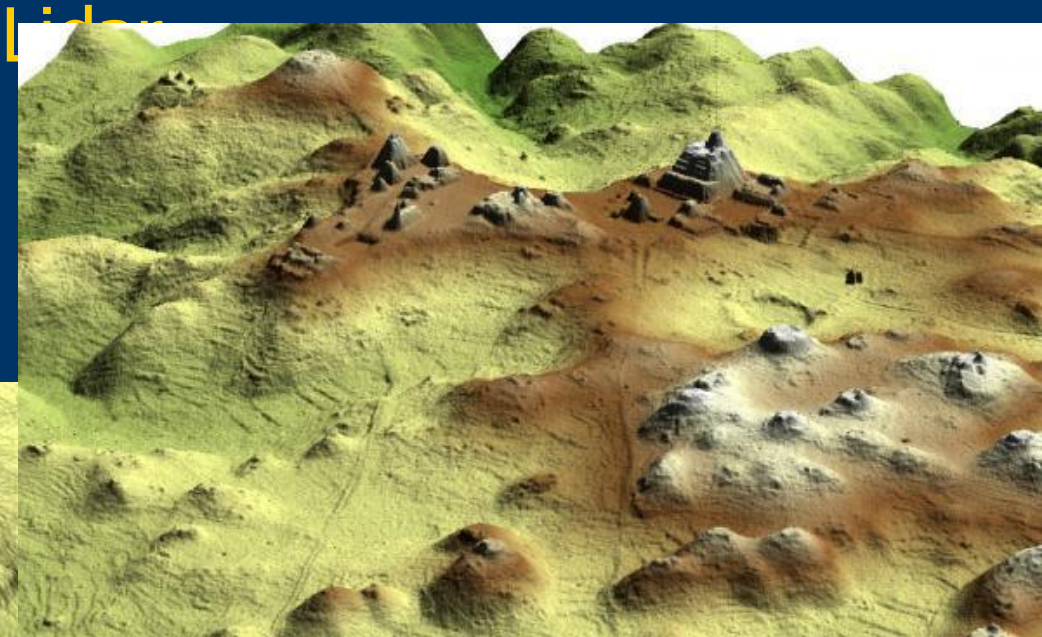


Mapping Cultural Features at Petra with Aerial and Satellite Imagery





Caracol,
Belize



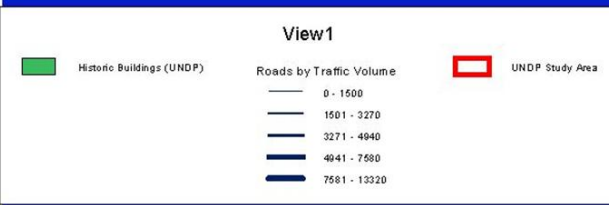
Arlene Chase

Lidar scan made possible by
NASA ROSES

Space Archaeology Program
grant

The First Step: Geospatial Analysis of the Landscape

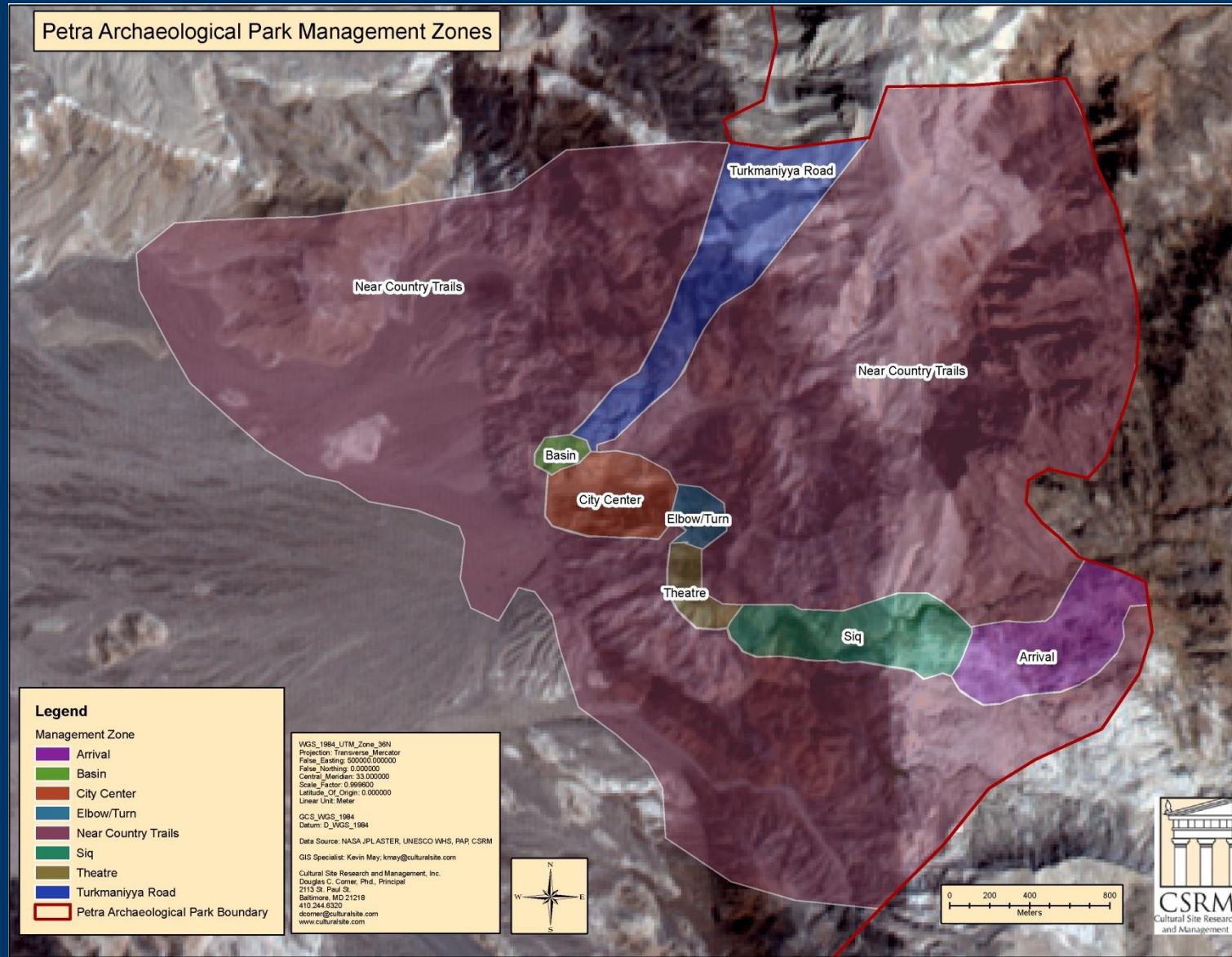
Key Roads Into the Cape Coast Historic Core



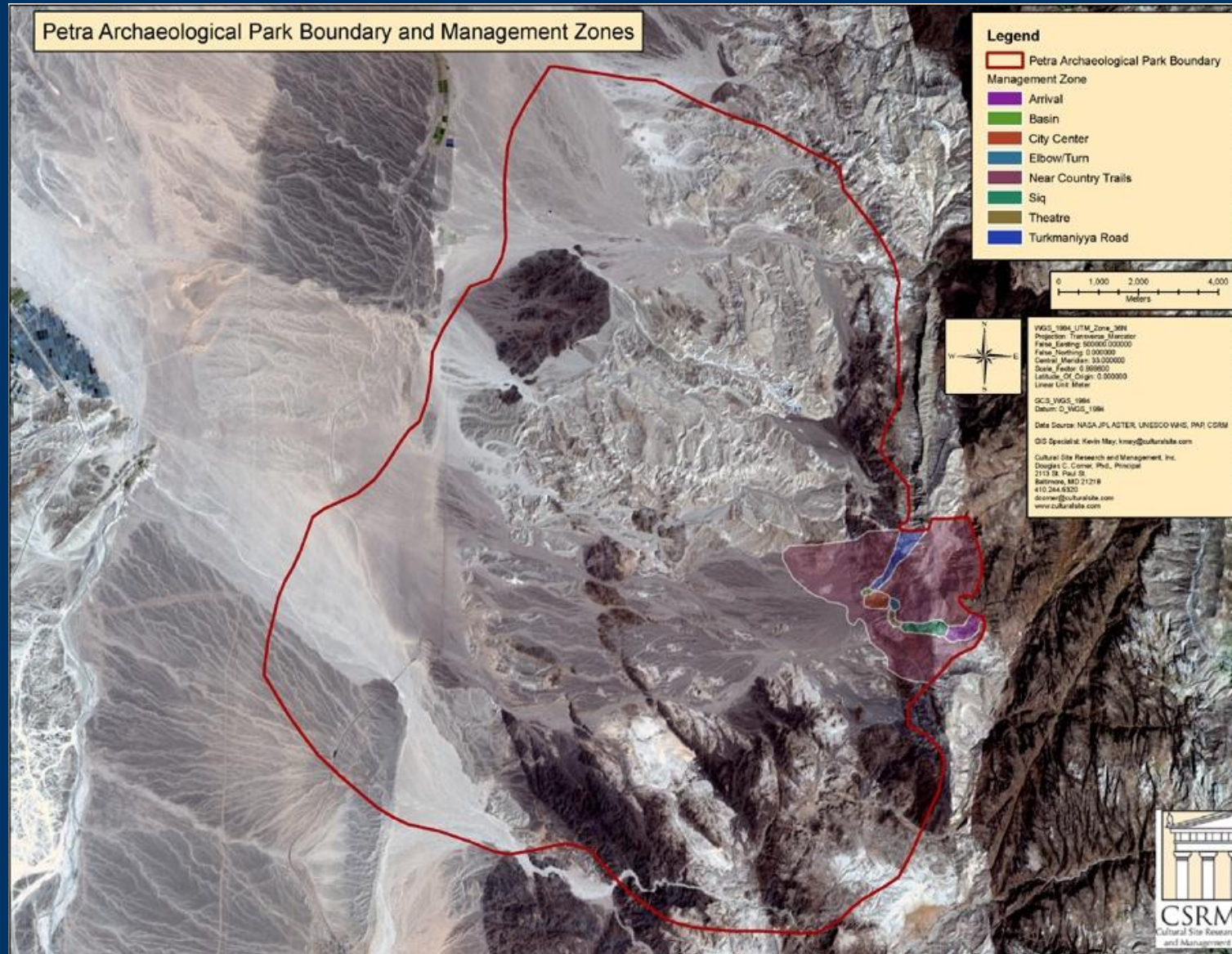
Selected Structures of Interest



Developing Management Zones



Developing Management Zones



Based on
distribution of
cultural and
natural
resources,
landscape
constraints,
sensitivity of
resources,
desired uses
and experiences

Petra WHS
boundary shown

Desired Conditions for Petra Management Zones



City Centre

Clear explanation and depictions of ancient city-scape that do not depend upon destructive research or devices

Theatre

Clear but non-intrusive interpretive devices that do not degrade resource.

Siq

Quite, natural smells and sounds, clear but non-intrusive interpretive media.

Basin

Clean restroom and dining facilities. Clear instructions as to options for returning to modern world.

Turkmaniyya

Traditional but comfortable modes of transport offered in non-aggressive fashion, interpretive devices to interpret features along Turkmaniyya, summary of experiences in park, and suggestions for additional ones (e.g., Ad-Dayr, High Place, Wadi Sabra, etc.)

Turkmaniyya

Near Country Trail

Basin

Elbow Turn

City Centre

Theatre

Siq

Arrival

Near Country Trail

Opportunities for more intimate experience with nature and culture, patrols to ensure that undesirable activities are not allowed

Arrival

Order and cleanliness, clarity of message, effective presentation to visitor of options and the location of basic services. Inviting and engaging atmosphere, friendliness and hospitality. Opportunity to rest and renew before entering Siq.

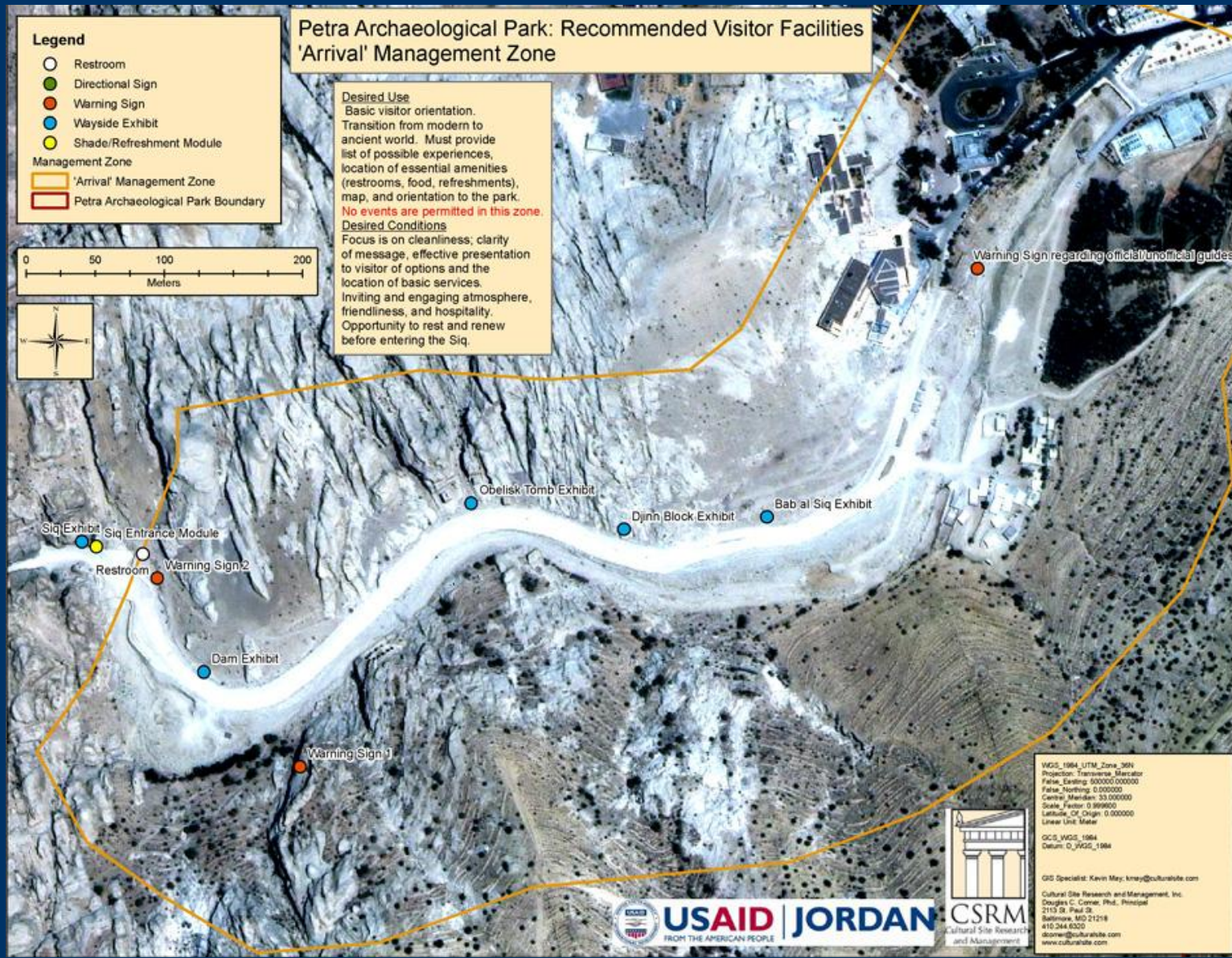
Elbow Turn

Clean restrooms, opportunities for comfortable rest, opportunities to rehydrate, clear but non-intrusive interpretive devices, opportunity to acquire additional interpretive media.

Mapping Existing Conditions



Mapping Desired Conditions



3D Solid Model Petra Exhibition



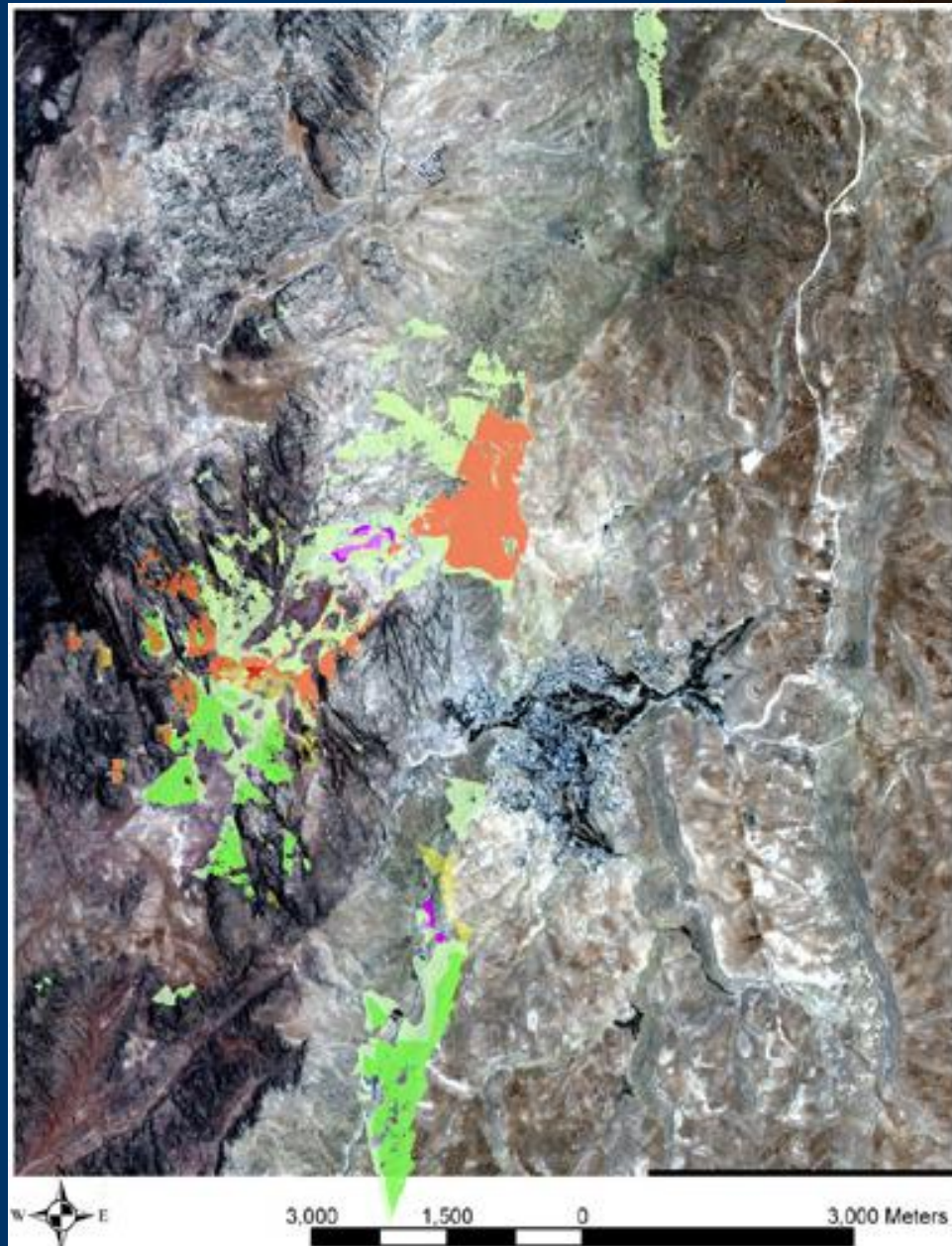
Flyover Model Petra Exhibition



Flood Model Petra Exhibition



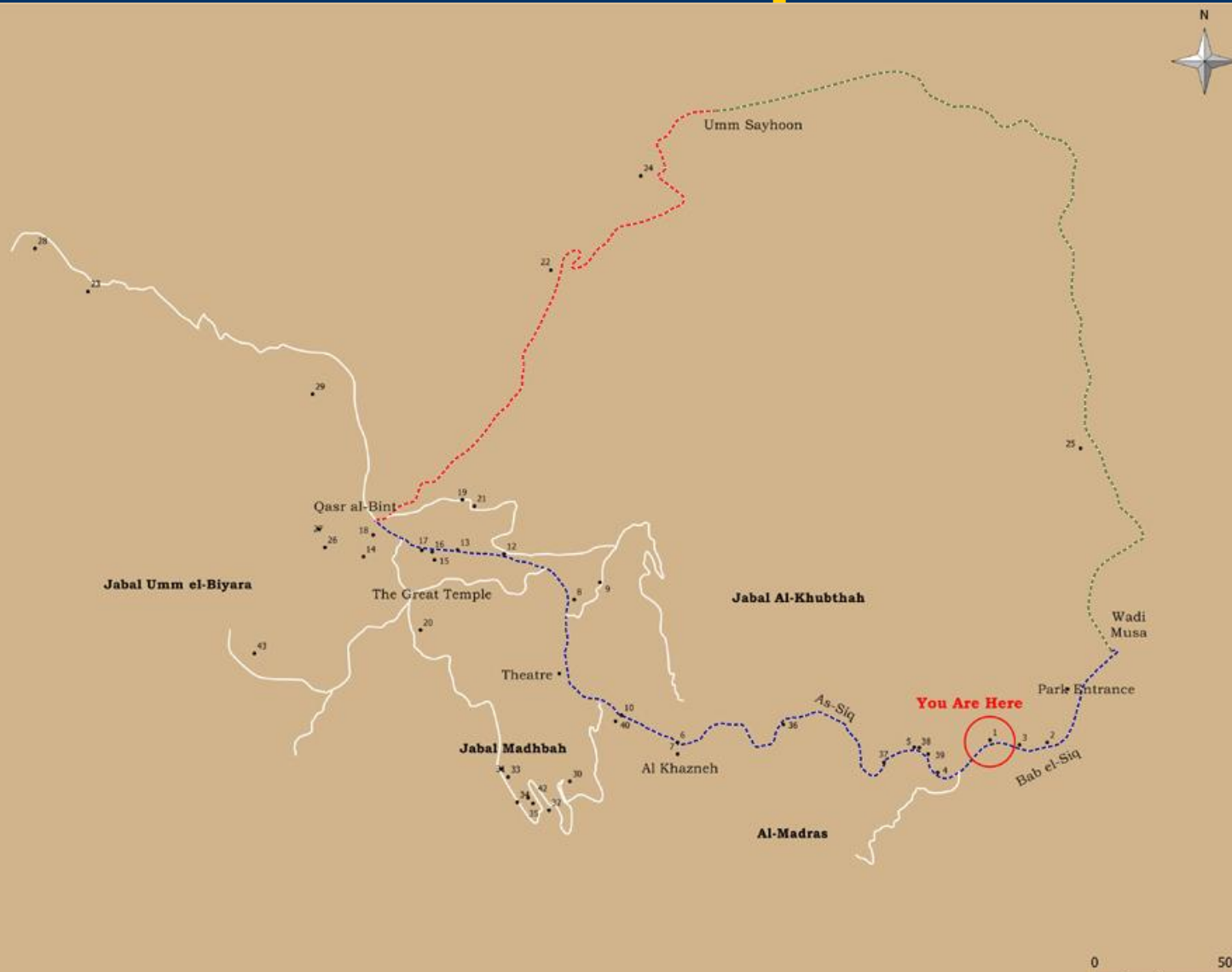
Modeling Viewshed Visually Intrusive Areas in Purple



2D Conventional Map

Wayside Exhibits

1. Obelisk Tomb and Bab el-Siq Triclinium
2. Bab el-Siq
3. Djin Blocks
4. Modern barrage dam across Siq
5. Siq Entrance
6. Camel Caravan Reliefs
7. Al-Khazneh
8. Royal Tombs
9. Urn Tomb
10. Street of the Facades
11. Main Theater
12. Nymphaeum
13. Colonnaded Street
14. Unfinished Tomb
15. Ornamental Garden and Pool Complex
16. The 'Great Temple' Complex
17. The Temenos Gate
18. Qasr al-Bint Temple Complex
19. Temple of Winged Lions
20. Stately Residence on Ez-Zantur Hill
21. The Church Complex of Petra
22. Turkmaniyya Tomb
23. Ad-Dayr
24. Anjar Quarries
25. Crusader Fortress at Al Wu'ayra
26. The Columbarium
27. Al-Habis Mountain
28. Room No. 468
29. The Lion Triclinium
30. High Place of Sacrifice
31. Wadi Al-Farasa
32. The Lion Fountain
33. The Renaissance Tomb
34. The Colored Triclinium
35. The Garden Hall
36. Sabinos Alexendros Station
37. Paved Road
38. The Tunnel
39. Wadi Al Mudhlum
40. Tomb 67
41. Tomb No.4
42. The Tomb of the Soldier
43. Umm al-Biyara



Aerial and Satellite Remote Sensing at Petra

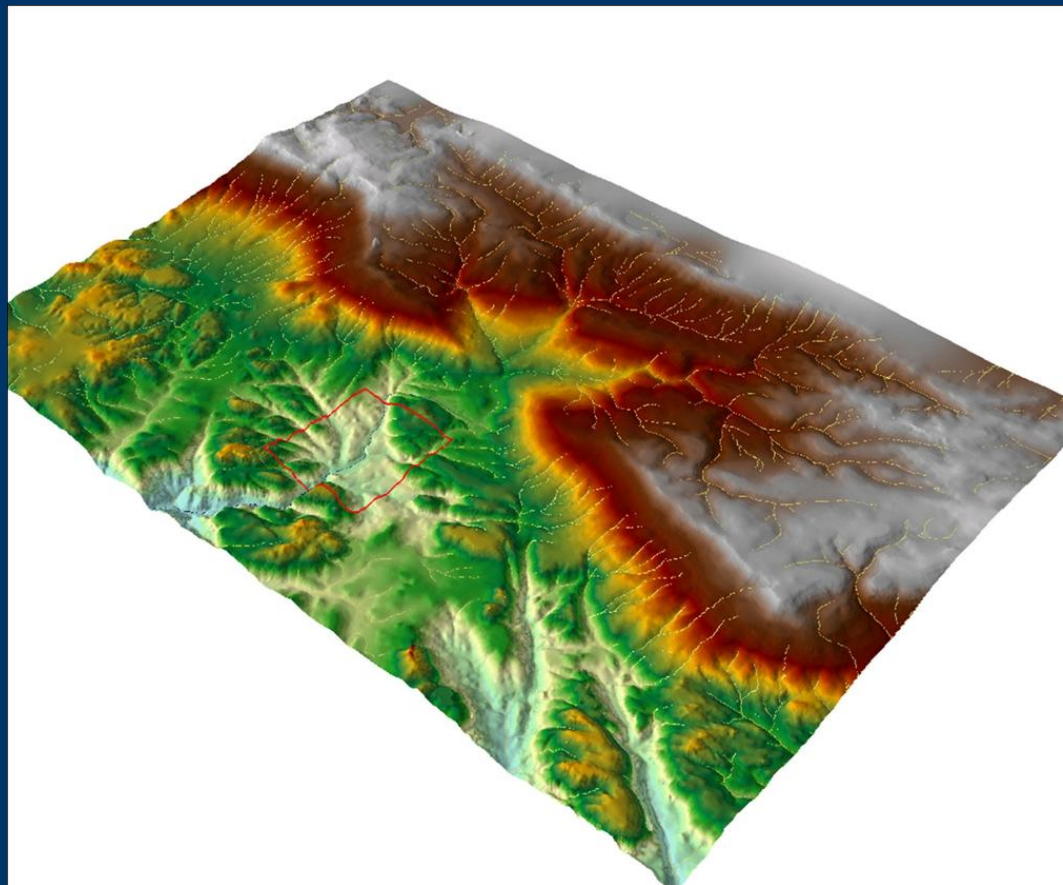
A valuable tool that has been
elaborated over time

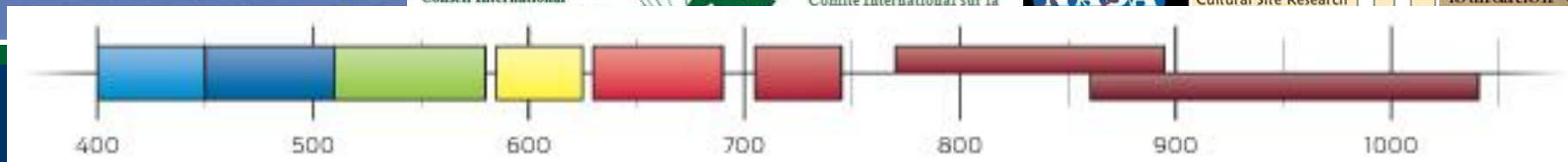
Uses data sets that are
readily available

It has not become obsolete

Has been used for planning
management,
interpretation, and
research at Petra and
surrounding areas.

All functions are
complementary to each
other with GIS technology

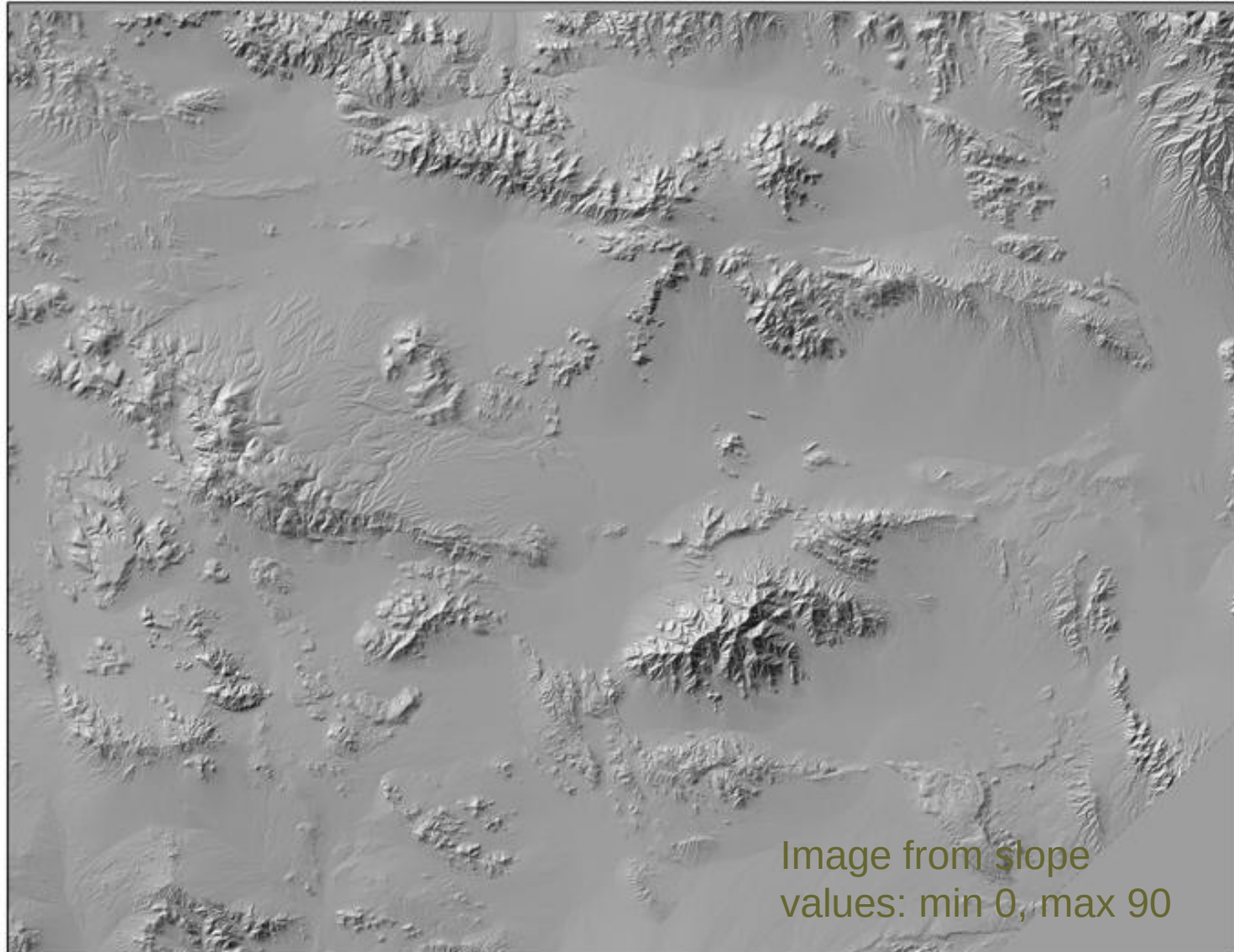




Data Sets: Worldview-2 (Digital Globe) Spectral Irradiance

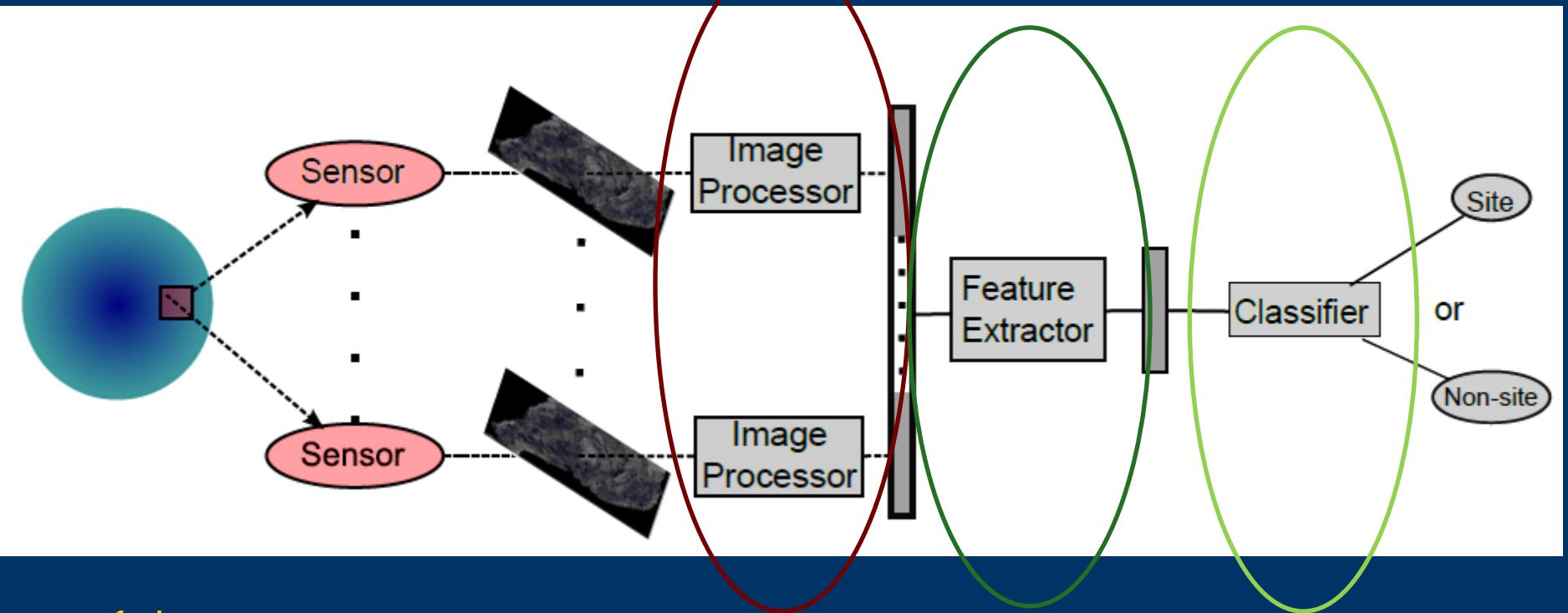
Spectral Band	Bandwidth (μm)	Effective Bandwidth, $\Delta\lambda$ [μm]	Spectral Irradiance [W-m-2- μm^{-1}]
Panchromatic (Not Used)	0.450 – 0.800	0.2846	1580.814
Coastal	0.400 – 0.450	0.0473	1758.2229
Blue	0.450 – 0.510	0.0543	1974.2416
Green	0.510 – 0.580	0.063	1856.4104
Yellow	0.585 – 0.625	0.0374	1738.4791
Red	0.630 – 0.690	0.0574	1559.4555
Red Edge	0.705 – 0.745	0.0393	1342.0695
Near IR 1	0.770 – 0.895	0.0989	1069.7302
Near IR 2	0.860 – 1.040	0.0996	861.2866

Slope Values are the 9th Feature



Diagrammatic Representation of Bayesian Protocol

Four Steps



1. Images
corrected for
atmospheric
interference, etc.

2 a. Harvests
numbers from
pixels, 2 b. Uses
annuli method

3. Using principal
component analysis
(could use other
approaches)

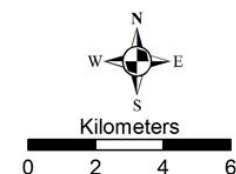
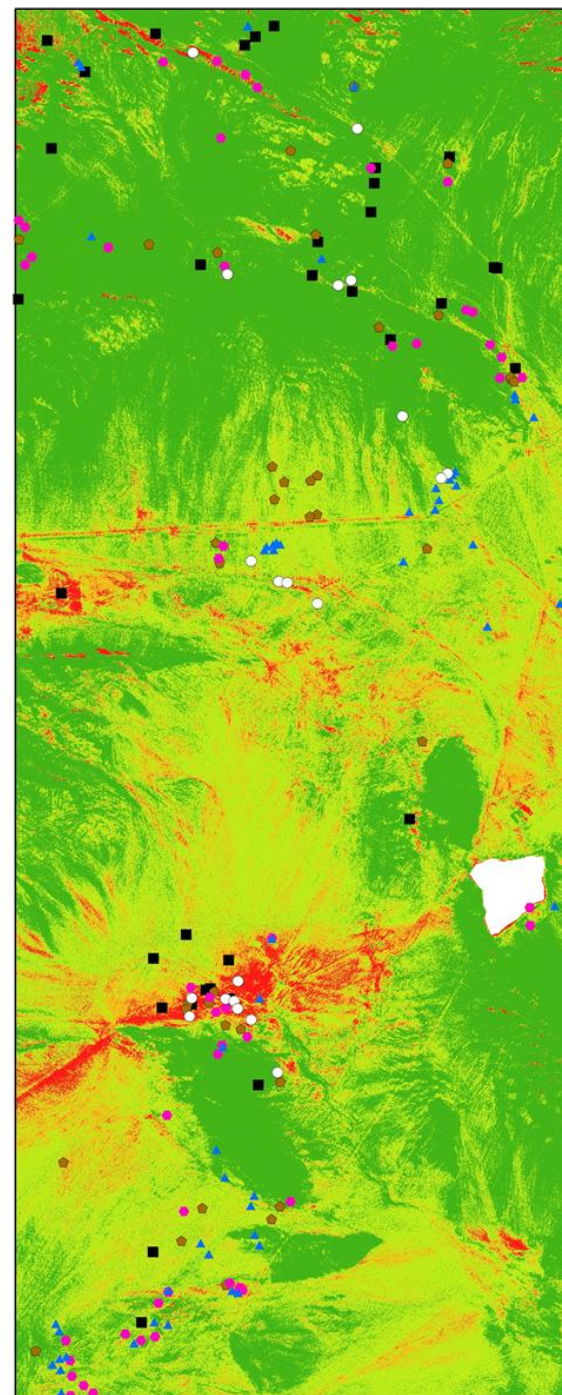
4. Using linear
discriminate
analysis (could use
others)

	Red	Yellow	Green	N
Eligible	17	3		20
Ineligible	8	41	3	52
Disturbed/Destroyed	8	46	13	67
	33	90	16	139
Isolated Artifacts (Diagnostics)	26	16	6	48

	Red	Yellow	Green	Total
Eligible	85%	15%	0%	100%
Ineligible	15%	79%	6%	100%
Disturbed/Destroyed	12%	69%	19%	100%
Isolated Artifacts (Diagnostics)	54%	33%	13%	100%

	Red	Yellow	Green	Total
Number of Sites in Zone	33	90	16	139
Percentage of Total Sites in Zone	24%	65%	11%	100%
Percentage of Zone in Test Area	8%	52%	40%	100%
Percentage of Eligible Sites	85%	15%	0%	100%

Results, East Swath, Mojave Desert



Mapping Archaeological Landscapes from Air and Spaceborne Platforms

1. Historic Air and Spaceborne Imagery
2. Multispectral and Hyperspectral Imagery
3. SAR (Synthetic Aperture Radar)
4. LiDAR (Light Detection and Ranging)
5. Archaeological Site Detection and Modeling

